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North Korea's Nuclear Weapons: How Soon an Arsenal?

Summary

In December 2002, North Korea ended the 8-year-old freeze on its nuclear program by dismantling monitoring equipment, expelling inspectors and restarting operations at its plutonium production facilities. The CIA has assessed that North Korea could produce 5-6 weapons by mid-2003, in addition to 1 or possibly 2 weapons it might already have. This report analyzes what may be North Korea's next steps in producing plutonium-based nuclear weapons, provides a notional timeline, and discusses potential signs of North Korean activities. It will be updated as events warrant.

Background

In the early1980s, U.S. satellites tracked a growing indigenous nuclear program in North Korea. North Korea's small reactor at Yongbyon (5MWe), capable of producing about 6kg of plutonium per year, began operating in 1986.[1] Later that year, U.S. satellites detected high explosives testing and a new plant to separate plutonium (a necessary step before turning the plutonium into metal for a warhead). In addition, the construction of two larger reactors (50MWe at Yongbyon and 200MWe at Taechon) added to the mounting evidence of a serious, clandestine effort. Although North Korea had joined the Nuclear Nonproliferation Treaty in 1985, nuclear safeguards inspections began first in 1992. Those inspections raised questions about how much plutonium North Korea had produced covertly that still have not been resolved. In 1994, North Korea signed the Agreed Framework with the United States, agreeing to freeze its plutonium programs and eventually dismantle them in exchange for several kinds of assistance.[2] Western intelligence agencies at that time estimated that North Korea had produced an amount of

[1] 5MWe is a power rating for the reactor, indicating that it produces 5 million watts of electricity per day (very small). Reactors are also described in terms of million watts of heat (MW thermal). Although the reactor was optimized to produce plutonium, and is not connected to any electricity grid, North Korea has always referred to it by the 5MWe rating.

[2] See CRS Issue Brief IB91141, *North Korea's Nuclear Weapons Program*, by Larry A. Niksch, on all aspects of the 1994 Agreed Framework.

plutonium equal to that needed for one to two bombs. Other sources suggested North Korea had enough material to produce 4-5 bombs.

This report analyzes what may be North Korean steps to producing plutonium-based nuclear weapons, provides a notional timeline, and suggests potential signs of North Korean activities. Although the current crisis was ignited by October 2002 revelations of a North Korean clandestine uranium enrichment program, North Korea appears to be still in the construction phase.[3] Current estimates, for example, that North Korea could produce 5 or 6 nuclear weapons in 6 months, focus solely on plutonium production.[4]

Weapons Production Milestones

Most proliferation analysts agree that the key obstacle in nuclear weapons development is acquiring special nuclear material – plutonium-239 or highly enriched uranium (HEU).[5] Producing these two materials is technically challenging; in comparison, many experts believe weaponization to be a relatively easy process.[6] This may help explain intelligence estimates that countries like Iraq could assemble a device within months if they acquired fissile material from elsewhere. In general, outside assistance often helps tip-off clandestine programs. North Korea is, however, largely self-sufficient, with industrial-scale uranium mining, and plants for milling, refining, conversion, fuel fabrication, reactors, and reprocessing. Key steps include fuel fabrication, irradiation in reactors, and reprocessing of fuel. North Korea makes magnox fuel -- natural uranium (>99%U-238) metal, wrapped in magnesium-alloy cladding. A fuel core for the 5MWe reactor contains 8000 small fuel rods. The fuel fabrication plant may have fallen into disrepair, according to one source, but North Korea has a supply of fresh (unirradiated) fuel for the 5MWe reactor.[7]

When irradiated in a reactor, natural uranium fuel absorbs a neutron and then decays into plutonium (Pu-239). The longer the fuel remains in the reactor, the more it becomes contaminated by the isotope Pu-240, which can "poison" the functioning of a nuclear weapon.[8] Thus, a key consideration is how long the fuel must remain in the reactor to produce the right kind of plutonium. According to North Korea, the 5MWe reactor operated from January 1986 to April 1994 but many analysts believe some (or possibly all) of all the fuel core was removed in 1989. Spent or irradiated fuel, which poses radiological hazards, must cool after removal from the reactor. The length of cooling, estimated by some at 5 months, is proportional to the fuel burn-up.

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[3] Unclassified CIA point paper distributed to Congressional staff on November 19, 2002.

[4] David E. Sanger, "U.S. Eases Threat on Nuclear Arms for North Korea," *New York Times*, December 30, 2002.

[5] Highly enriched uranium (HEU) is uranium comprised of 20% or more U-235 and is commonly used as fuel in research reactors. Weapons-grade uranium is 90% or more U-235.

[6] The physical principles of weaponization are well-known, but producing a weapon with high reliability, effectiveness and efficiency without testing may provide other challenges.

[7] David Albright, President of the Institute for Science & International Security, January 10, 2003

[8] Plutonium that stays in a reactor for a long time (reactor-grade, with high "burn-up") contains about 20% Pu-240; weapons-grade plutonium contains less than 7% Pu-240.

Reprocessing – or separating the plutonium from waste products and uranium – is the next step. North Korea uses a separation process similar to that used in the United States. After shearing off the fuel cladding, the fuel is dissolved in nitric acid. Components (plutonium, uranium, waste) of the fuel are separated into different streams using organic solvents. In small quantities, separation can be done in hot cells, but larger quantities require significant shielding to prevent deadly exposure to radiation.[9]

Many experts agree that North Korea has mastered the engineering requirements of plutonium production. Its 5MWe nuclear reactor operated from 1986 to 1994, and North Korea separated plutonium in hot cells and tested its reprocessing plant. On the other hand, some analysts have reported that the 5MWe reactor, which was thought to be a test reactor rather than a plutonium production reactor, operated at low efficiencies and one IAEA official called the reprocessing plant "extremely primitive" when he toured it in 1992. A key consideration for a crash program to build nuclear weapons is how quickly the reprocessing plant can become operational; for building a larger arsenal, the completion of the two larger reactors is key. Another source of fissile material could be the Soviet-supplied IRT research reactor, which may have been used in the past to irradiate uranium targets to produce plutonium, and could be operated in that manner in the future.

There is little information on whether North Korea has a workable nuclear weapons design. The simplest nuclear weapon design, a gun-type assembly, cannot use plutonium. Many believe North Korea to be capable of manufacturing implosion-type devices, which require sophisticated lenses of high explosives to compress plutonium in the core. As long ago as 1986, U.S. satellites detected high explosive testing with the kind of compression patterns associated with implosion devices, although North Korea claimed the tests were for civilian purposes.[10] There have been reports of Soviet scientists aiding North Korea, although CIA officials in the mid-1990s reportedly said that North Korean scientists did not receive training in nuclear weapon technologies from Russia or China.[11] Although states that have developed nuclear weapons typically have first used relatively crude delivery methods, North Korea is one of the few that has produced concurrently ballistic missiles with sufficient range and payload to carry nuclear warheads. Nonetheless, such a warhead would need to be small and light enough to fit on a missile, and robust and sophisticated enough to tolerate the variety of conditions encountered through a ballistic trajectory.

Estimating Nuclear Material Production

Estimating nuclear stockpiles is difficult, but in North Korea's case, it may be more important to know when it crosses the threshold between a demonstration capability (1-2 bombs) and a modest deterrent (10-20 bombs). Without empirical data, estimates rely on assumptions of how much plutonium is produced and how much plutonium is needed per

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[9] Hot cells are heavily shielded rooms with remote handling equipment. They can be used for examining irradiated targets or reactor fuel.

[10] Don Oberdorfer, *The Two Koreas,* (MA: Addison-Wesley), 1997, p. 250.

[11] David Albright, Frans Berkhout ,William Walker, *Plutonium and Highly Enriched Uranium 1996: World Inventories, Capabilities and Policies*, Oxford University Press, 1997, p. 307.

bomb. (The IAEA has stated it cannot determine how much plutonium North Korea has produced already without physical samples of the reactor fuel rods, knowing their exact position in the reactor core and inspecting a suspected waste site.) There is unlikely to be any data at all on weaponization. To determine how much plutonium is produced, key estimates include: the average power level of the reactor; days of operation; how much of the fuel loading is reprocessed and how quickly, and how much plutonium is lost to production processes. According to North Korea, the 5MWe reactor performed poorly in the early years and the rods were unevenly irradiated. Maintenance reportedly was performed at the reprocessing plant in 2002, but it is not clear that the plant has run reprocessing campaigns beyond the "hot test" in 1990. North Korea told the IAEA that during the 1990 test, it recovered 62 grams of plutonium, losing almost 30% in the waste streams.[12] Although this is not surprising for a plant starting up, it is difficult to assess when the plant would improve its efficiency. Another consideration is whether or not the reprocessing plant is operated continuously. The size of the plant, or capacity, is estimated at 220-250 tons of spent fuel annually, about 4-5 times the amount of fuel in the 5MWe reactor.

Estimates of how much plutonium is needed per bomb vary according to judgements about North Korea's technical sophistication. Although the international standard is 8kg of Pu per weapon(and 25kg for HEU), technical experts agree that it is possible to make nuclear weapons with less than half that amount. Many of the higher estimates of North Korea's nuclear weapons production assume between 4 and 6 kg of plutonium per weapon.

What Does North Korea Have Now?

In 1994, Western intelligence agencies estimated that North Korea had produced an amount of plutonium equal to that needed for one to two bombs. One analyst estimated that North Korea had separated between 6 and 10kg of plutonium in the late 1980s, and that at least 8 kg of plutonium was needed for a first bomb, because of losses in the production process, but the scraps could be saved and used potentially in a second bomb.[13] Other sources ranged as high as North Korea being able to produce 4-5 bombs.

Recent assessments seem to emphasize that North Korea has assembled weapons. Secretary of State Powell stated in December 2002 that "We now believe they [North Koreans] have a couple of nuclear weapons and have had them for years."[14] An unclassified CIA paper in November 2002 stated that the "North has one or possibly two weapons using plutonium it produced prior to 1992."[15] However, the CIA paper stated that this was an assessment that has not changed since the 1990s. In that time, the CIA has consistently reported that North Korea "has probably produced enough plutonium for

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[12] David Albright and Kevin O'Neill, editors, *Solving the North Korean Nuclear Puzzle*, ISIS Report, ISIS Press, 2000, p. 88.

[13] Ibid, pp. 111-126.

[14] Transcript of December 29, 2002 "Meet the Press" (http://www.msnbc.com/news/852714.asp)

[15] CIA unclassified point paper distributed to Congressional staff on November 19, 2002.

at least, one, and possibly two, nuclear weapons."[16] Evidence connected to weaponization, if it exists, has not been revealed publicly.

Adding to the Arsenal

Reprocess Existing Fuel. The likely quickest source of additional fissile material is to reprocess the spent fuel from the 5MWe reactor, now in sealed canisters, which contains an estimated 25 to 30kg of weapons-grade plutonium (5 to 6 weapons). The sealed canisters do not create a technical barrier to reprocessing; contrary to North Korean assertions about corroding fuel rods, the canisters simply keep track of the fuel rods. Given the need to remove the fuel cladding on individual rods mechanically, the canisters would need to be opened first, either *in situ*, or in a shielding cask.

The fuel rods likely would be moved by truck at night to the reprocessing plant within the same facilities complex. In 1992, IAEA inspectors estimated the reprocessing plant to be 80% complete (with one reprocessing line) with 40% of equipment installed. By 1994, the second reprocessing line was nearly complete, but not all instrumentation had been installed. One analyst estimated reprocessing could begin in one to three months.[17] According to one report, in December 2002, China shipped North Korea 20 tons of tributyl phosphate, which is a key ingredient (organic solvent) in reprocessing.[18] Although lack of some equipment did not prevent the reprocessing plant from small-scale separations, it is unclear what obstacles might arise if large-scale production begins. Assuming that one reprocessing line was operating continuously, separations could take between 3.5 and 5 months.[19] If North Korea reprocessed about 11 tons/month, it might produce enough plutonium for 1 bomb per month. The shortest estimate would include: 1 month to ready the reprocessing plant and prepare fuel for reprocessing, 3 months to reprocess and 1-2 months to convert the material into metal and shape a weapon. A longer estimate would include: 3 months to ready the plant and fuel, 5 months to reprocess and 1-2 months to convert, for 10 months total. In contrast, IAEA officials have estimated that North Korea could take two years to produce 25 kg of separated plutonium.[20] North Korea may also be able to reprocess some material in existing hot cells, perhaps in the isotope production laboratory associated with the IRT reactor.

Make New Plutonium. North Korea reportedly has moved fresh fuel rods to the 5MWe reactor. It may be possible to load the reactor with up to 8000 fuel rods by the end of January 2003. However, Bush administration and other officials have estimated that it take one year to 18 months before the reactor is online. Similar estimates are based on resolving engineering, safety, and personnel readiness issues arising from the reactor's

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[16] See *Acquisition of Technology Relating to Weapons of Mass Destruction and Advanced Conventional Munitions*," (http://www.cia.gov/cia/publications/bian/bian_jan_2003.htm)

[17] Jim Wolf, "U.S. Fears North Korea Could Get 50 Bombs a Year," *Reuters*, December 24, 2002.

[18] Bill Gertz, "China Ships North Korea Ingredient for Nuclear Arms," *Washington Times*, December 17, 2002.

[19] Albright, *Plutonium and Highly Enriched Uranium 1996,* p. 305.

[20] Mark Hibbs, "Pyongyang May Operate Separation Plant," *Nuclear Fuel*, December 23, 2002.

being closed for six years.[21] However, North Korean tolerances for engineering, health, and safety risks are unknown. Although a common estimate is that the reactor generates 6kg per year, the reactor would likely be operated for several years before fuel is withdrawn. In 3 years, it could generate about 14-18kg of plutonium, enough for 2 to 3 weapons. Shorter cycles are possible, but would waste considerable fuel. Assuming a 6-month cooling period for plutonium, North Korea would be ready to reprocess by June 2006, and ready to convert into metal by December 2006.

Bring New Reactors On-Line. North Korea may also finish construction on the reactors at Yongbyon (50Mwe) and Taechon (200MWe), which are both several years from completion. According to one estimate, the reactor at Yongbyon could produce between 40 and 53 kg of weapons-grade plutonium per year (5 to 10 nuclear weapons). The reactor at Taechon is much larger; if optimized to produce plutonium, it may be capable of generating between 140 and 180kg annually, operating at 60-80% power; if optimized to produce electricity, it likely could generate 90-120kg of reactor-grade plutonium.[22] The CIA estimates that together, the two reactors could generate about 275kg of plutonium per year.[23] In addition, the Soviet-supplied IRT reactor could produce 2-4 kg of plutonium per year by irradiating additional targets, assuming North Korea acquires HEU fuel rods.

Likely Indications of North Korean Activity

Without IAEA inspectors and monitoring systems, the outside world must rely on remote monitoring to detect North Korea's next steps in nuclear weapons production. Some activities, like construction (reactors at Yongbyon, Taechon), and reactor operations and shutdowns, have distinct signatures. Yet, remote monitoring is of little use in revealing specific details like how much plutonium is produced or separated. While we may know now how fuel rods are transferred, we may not be able to detect that transfer. A key signature would be reprocessing. Although intelligence officials reportedly warned the White House that spy satellites might not detect reprocessing, many experts believe North Korea's plant could give off environmental signatures that can be detected through other means. It may be possible to detect continuous or batch processing at the reprocessing plant, but it likely will not be possible to know how much plutonium it separates. As in the past, it may be possible to detect additional high explosives testing and probably, nuclear tests if they are conducted, even underground. It probably will not be possible to detect when North Korea mates warheads with missiles. Additional information could be obtained from defectors or human intelligence sources, but these are typically rare.

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[21] ibid.

[22] Albright, *Plutonium and Highly Enriched Uranium 1996,* p. 301.

[23] CIA unclassified point paper distributed to Congressional staff on November 19, 2002.